The implementation of peat ecosystems in mitigating the disaster of Riau forest fires

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Abstract. Forest fires are a frequent problem in Riau Province. Therefore, it is necessary to have mitigation efforts to deal with this forest fire disaster. One of the steps that can be taken is to implement peat ecosystems. This research then aims to see how the implementation of peat ecosystems can mitigate forest fire disasters, especially in Riau Province. This research will be carried out using a descriptive qualitative approach. The data used in this study comes from various previous research results that are still relevant to this research. The results of this study then found that in implementing this peat ecosystem, there are still challenges that need to be faced, such as climate change and land use. To overcome this, various opportunities such as technological developments and stakeholder collaboration can be implemented. In mitigating forest fire disasters, conservation and restoration of peat ecosystems is an important step to strengthen ecosystem resilience.

1 Introduction

Riau Province, located on the Indonesian island of Sumatra, has abundant natural resources, including vast peat forests. However, over the past few decades, Riau has faced a serious problem in the form of recurring catastrophic forest fires. Forest fires in Riau not only threaten the natural environment but also cause significant economic and social losses. Peat ecosystems in Riau play an important role in regulating the climate, storing carbon, and serving as habitats for various species of flora and fauna [1]. However, these ecosystems are highly susceptible to fires, especially during long dry seasons and dry weather conditions. Factors such as land clearing for agriculture, forest encroachment, and unsustainable management have led to the degradation of peat ecosystems, increasing the risk of forest fires [2].

The implementation of peat ecosystems in forest and land fire disaster mitigation involves a series of conservation and restoration efforts aimed at maintaining and strengthening hydrological functions and ecosystem resilience. Some of the efforts that have been made include restoration of peat vegetation, construction of irrigation channels, integrated fire control, and sustainable land management [3]. One important aspect that needs to be considered in the implementation of peat ecosystems is a thorough understanding of the

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condition of peat ecosystems in Riau. Through careful mapping and monitoring, we can identify locations prone to forest fires and develop appropriate mitigation strategies [4].

It is also important to involve various stakeholders in peat ecosystem implementation. The government, local communities, companies, and research institutions need to work together to formulate policies, develop action plans, and implement programmes that support forest fire disaster mitigation [5]. Over the past few years, several efforts have been made to implement peat ecosystems in forest fire disaster mitigation in Riau. However, a thorough evaluation of the success and impact of these efforts is still needed to identify lessons learned and recommendations that can be used to improve and expand mitigation activities [6].

Currently, there are complex challenges in implementing peat ecosystems to mitigate forest fire disasters in Riau. Factors such as climate change, economic interests, and social dynamics affect the ability and effectiveness of mitigation efforts [7]. Therefore, research that focuses on the implementation of peat ecosystems in mitigating forest fire disasters in Riau is very relevant and urgent to conduct. The information obtained from this research can provide a strong scientific basis for more effective mitigation policies and actions. This research is expected to provide a better understanding of the role of peat ecosystems in forest fire mitigation and provide recommendations that can be used to improve the effectiveness of future mitigation programmes.

Peat forests grow in waterlogged areas with a pH between 3.5 and 4.0, making the soil nutrient-deficient. In forests, peat is formed when fallen trees sink into mud, which contains little oxygen, so soil microorganisms cannot continue to break down plant material completely. In the end, the undecomposed material slowly turns into peat that can be up to 20 meters thick [8]. Peatland fires are the result of irresponsible utilization of peat swamps. Canals built by companies cause peatlands to become damaged, dry, and flammable [9]. One of the problems faced in peatland utilization is the low level of community participation in the formulation of peatland management policies. As a result, the implementation of these policies is still characterized by conflict, is dispute-prone, and is difficult to implement [10].

Peat literally refers to a pile of plant remains buried for hundreds to thousands of years. Epistemologically, peat is organic material that is naturally buried under conditions of excess water or water saturation, has no solid properties, and is partially or completely decomposed [11]. In the concept of pedology, peat is an area of soil that is strongly influenced by organic matter content. Ecologically, peat functions as a source and sink of carbon, which can produce greenhouse gas emissions that contribute to climate change and global warming [12]. Two forms of peat classification can be identified:

1.1 Ombrogenous peat

This type of peat is generally found in coastal areas and has a thickness of up to 20 meters. The peat water is highly acidic and has few nutrients (oligotrophic), especially calcium, because there is no supply of nutrients from outside sources. Therefore, plants growing on ombrogenous peat soils obtain nutrients from the peat itself and from rainwater [13].

1.2 Topogenous peat

This type of peat is rare and is usually formed in areas with indented topography, either on the coast or inland with obstructed drainage. The water is acidic and contains more nutrients than ombrogenous peat [14].

Peat soil is a type of soil formed from organic matter or the remains of past plants. Based on the USDA (2006) classification, peat soils belong to the histosol order. To be categorized as peat soil, the soil must meet certain requirements, namely having a minimum organic matter content of 12–18% Corganic (depending on the mineral fraction) and a minimum

thickness of 40 cm. In Indonesia, tropical peat organic matter is formed under anaerobic conditions [15]. This condition occurs due to continuous waterlogging of the organic material, resulting in the formation of a layer of organic material. This layer gets thicker and thicker until it reaches or exceeds a thickness of 40 cm, which is then referred to as peat soil. Peat organic matter comes from the vegetation that grows on it, and the nature and characteristics of peat soil are influenced by the type of vegetation of origin, topography, formation process, and age of the peat soil itself [16]. There is a difference between forest fires and land fires. Forest fires refer to fires that occur within forest areas, while land fires are fires that occur outside forest areas. Both forest fires and land fires can occur either intentionally or unintentionally [17].

A forest fire is an event in which a fire occurs that causes loss or disaster. Fires can occur due to a variety of factors, including uncontrolled burning, spontaneous natural processes, or deliberate actions. Natural processes are one example of a cause of forest fires, such as when lightning strikes a tree or building, a volcanic eruption releases a plume of embers, or friction between dry plant branches containing oil, which can be triggered by shifting winds and produce heat or sparks. In addition, forest fires can also occur due to deliberate human actions. Examples of human activities that can cause fires include burning agricultural land, plantations, industrial plantation forests (HTI), preparing land for raising livestock, and so on [18].

According to Darwiati and Tuheteru, whether on purpose or accidentally, human activity is to blame for almost 99% of forest and land fires in Indonesia. In that percentage, land conversion activities accounted for 34%, illegal cultivation 25%, agriculture 17%, social jealousy 14%, and transmigration projects 8%. Natural factors are only responsible for about 1% of fires. In addition, there are other factors that exacerbate forest and land fires and trigger them. These factors include climate extremes and the use of energy sources such as wood, coal deposits, and peat [19].

Every year, forest fires occur in Indonesia. Most of these forest fires are caused by human negligence or the intent to clear land on a large scale. Usually, this action is carried out illegally by plantation and forestry companies, either for agricultural, forestry, or plantation activities. Only a small proportion of forest fires are caused by natural factors, such as lightning or lava from volcanoes [20].

Forest fires often occur as a result of land clearing and the conversion of forests into plantations by burning debris, leaves, and crop residues. This burning method is considered cheap, easy, and efficient. However, due to the lack of control over such burning, fires can easily spread and cause widespread fires. Burning is usually used to clear land of existing vegetation before planting new crops. However, without proper supervision and control, fires can quickly spread to unwanted areas and cause fires that are difficult to control [21].

Weather factors play an important role in causing forest fires. Some of the weather factors that affect forest fires include wind speed and direction, air temperature, rainfall, groundwater conditions, and relative humidity. Weather conditions can affect the degree of dryness of vegetation, the ability of fire to spread, and the speed at which fire spreads. In addition, time also plays a role in forest fires. Time is closely related to the weather conditions that exist at that time. Time is differentiated between daytime and nighttime. Time conditions can affect the potential for forest and land fires [22].

Forest and land fires have become a serious problem every year in Indonesia, especially during the dry season. The impact of forest and land fires is not only limited to the area of the incident itself but also extends to neighboring countries. The haze produced by forest and land fires can spread widely to reach areas in ASEAN countries such as Singapore, Malaysia, and Brunei Darussalam. The impact of the spread of this smoke concentration is quite significant [23]. Visibility is reduced, air and land transportation are disrupted, and people experience an increased risk of upper respiratory tract infections. Social and economic issues

also arise from these fires. The impact of smoke from forest fires causes health problems such as acute respiratory infections (ARI), bronchial asthma, bronchitis, pneumonia (pneumonia), and eye and skin irritation. Dust levels in the air that exceed the threshold are the main cause of these health impacts [24].

In addition to the smoke that disrupts public health and land, water, and air transportation facilities, forest fires also cause other significant negative impacts, including ecological damage, decreased biodiversity, decreased economic value and forest productivity, and micro- and global climate change [25].

Forest fires have a direct impact on the mortality of populations and soil organisms and damage their habitats. Changes in soil temperature and the loss of litter can alter habitat characteristics and microclimate. Wildfires reduce the availability of food for soil organisms, and most soil organisms are susceptible to fire, resulting in rapid habitat changes and possibly significant declines in microorganism numbers. However, these negative impacts are generally temporary, and soil organism populations will eventually recover within a few years [26].

2 Methods

In this research, a descriptive qualitative approach and literature study method were used to explore relevant information on the role of peat ecosystems in fire mitigation. The descriptive qualitative approach allows researchers to describe in detail the characteristics and role of peat ecosystems in the context of fire, while the literature study method allows data collection from various reliable sources such as scientific journals, reference books, and research reports. The collected research data will be processed by the researcher, with the hope that conclusions can be drawn from this research [27].

3 Results and discussion

3.1 Contribution of peat ecosystems to forest fire disaster mitigation

Peat ecosystems have a unique ability to store water, which plays an important role in forest fire mitigation. The thick peat layer is able to absorb and store large amounts of water, forming a sustainable water source to maintain the surrounding moisture. In addition to storing water, peat ecosystems are also able to resist fire. The dense and compact structure of peat slows down fire propagation, allowing more time for fire intervention and suppression, thus minimizing the impact. The role of peat ecosystems as "natural firebreaks" is crucial in reducing the risk of forest fires. Peat has a high-water content and tends to be less flammable, which significantly inhibits the spread of fire. Figure 1. Illustration of the spatial distribution of KLHK forest and peatland fire monitoring system instruments through SiPongi+ spread across Riau Province in the period 2019–2023.

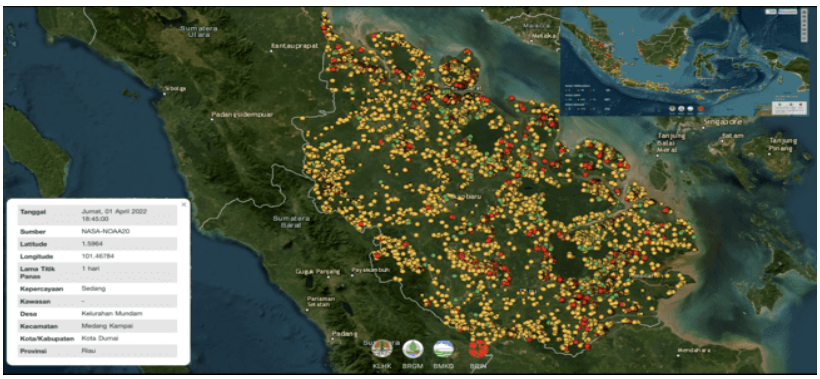

Fig. 1. Spatial distribution of KLHK peatland system forest and land fire monitoring instruments. Source: (SiPongi+, 2019-2023).

The hydrological function of peat ecosystems also plays a role in maintaining moisture and regulating the regional climate. Peat ecosystems serve as important water storage for rivers and groundwater sources. By maintaining the availability of water, peat ecosystems can maintain the humidity of the surrounding air, reduce the potential for drought, and create conditions that are not favorable for fire. In addition to the ability to store water, peat ecosystems also play a role in maintaining water quality. Peat is able to precipitate dissolved substances and drain water with a cleaner content. This has a positive impact on ecosystem sustainability and environmental health. Peat ecosystems also play a role in reducing greenhouse gas emissions and controlling climate change. When peat ecosystems burn, the carbon stored in the peat will be released into the atmosphere in the form of gas. By preserving peat ecosystems, greenhouse gas emissions can be reduced, and the impact of climate change can be slowed down. The distribution pattern of forest and land fires in Riau Province for five years from 2019 to 2023 through the forest and land fire monitoring system (SiPongi+) is presented in Figure 2.

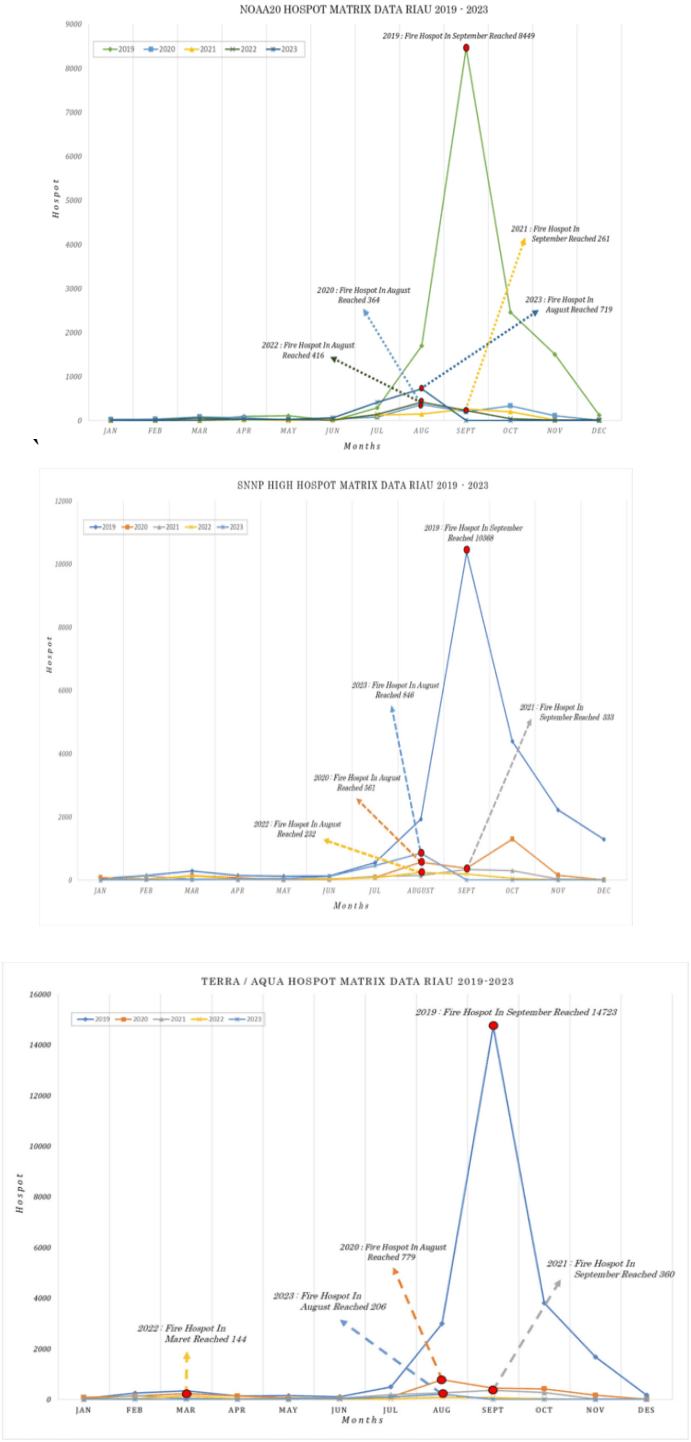

Fig. 2. Distribution pattern of forest fires in Riau Province 2019-2023.

The sustainability of peat ecosystems also impacts biodiversity. A healthy peat ecosystem provides an important habitat for many species of flora and fauna, including endangered species. By protecting peat ecosystems, we are also protecting the biodiversity within them. The implementation of conservation and restoration practices for peat ecosystems is key to improving their contribution to mitigating forest fires. Efforts to restore peat vegetation and sustain sustainable management will strengthen the hydrological function and fire resistance of peat ecosystems.

The importance of strengthening the role of peat ecosystems in forest fire mitigation underscores the need for sustainable protection and management. In this context, there needs to be cooperation between the government, communities, companies, and research institutions to maintain the sustainability of peat ecosystems. Awareness of the importance of peat ecosystem conservation and restoration in mitigating forest fires needs to be widely socialized. Education and socialization of the community about the benefits of peat ecosystems as an effective mitigation tool will increase participation and support in maintaining and restoring peat ecosystems in Riau.

3.2 Implementation of peat ecosystem conservation and restoration efforts

Restoring peat vegetation is an important step in strengthening the resilience of peat ecosystems. Replanting and rehabilitating degraded peatlands can increase the sustainability of the peat ecosystem and strengthen its ability to store water, resist fires, and maintain moisture. In addition to vegetation restoration, the construction of irrigation canals is also an important effort to maintain water availability in peat ecosystems. Well-designed irrigation canals can help maintain optimal water levels in the peat, preventing drought and maintaining the moisture needed to reduce the risk of fire. Integrated fire management is key to preventing and reducing forest fires in peatlands. This approach includes fire prevention through regular patrols, close surveillance, and early detection using advanced technology and monitoring systems. Table 1 summarizes land and forest area in Sumatra, Indonesia, for the period 2019–2023.

Table 1. Recapitulation of the area of land and forest (Ha) Sumatera Indonesia.

Province	2019	2020	2021	2022	2023
Aceh	730,00	1.078,00	1.267,00	3.716,00	1.511,63
Bengkulu	11,00	221,00	93,00	1.620,00	25,61
Jambi	56.593,00	1.002,00	540,00	918,00	153,92
Lampung	35.546,00	1.358,00	5.411,00	7.989,00	2.992,76
Riau	90.550,00	15.442,00	8.970,00	4.915,00	2.220,71
Sumatera Barat	2.133,00	1.573,00	2.068,00	9.832,00	1.082,61
Sumatera Selatan	336.798,00	950,00	950,00	3.723,00	1.178,50
Sumatera Utara	2.514,00	3.744,00	3.744,00	7.516,00	1.539,78
Total	524.875,00	25.368,00	23.043,00	40.229,00	10.705,52

Source: Forest and land fire monitoring system (SiPongi+)

In addition, infrastructure development that supports fire mitigation also needs to be considered. This includes the construction of road networks, effective fire suppression, and improved accessibility to fire locations to accelerate fire suppression response. Implementing peat ecosystem conservation and restoration efforts requires strong collaboration between the government, communities, and the private sector. Through sustainable partnerships,

coordination of peatland management, law enforcement against illegal burning, and better monitoring of activities that damage peat ecosystems can be achieved. In this context, the importance of counselling and educating local communities on the importance of peat ecosystem conservation should not be overlooked. Communities need to be given a good understanding of the benefits of peat ecosystems and their role in maintaining and restoring them.

Skilled human resources trained in peat ecosystem management are also needed. Training and education on sustainable management practices and fire mitigation methods need to be provided to experts, land managers, and firefighters. In implementing peat ecosystem conservation and restoration efforts, it is important to consider social justice aspects. The active participation of local communities, including indigenous groups, in decision-making and benefit sharing from conservation and restoration efforts is essential.

Regular evaluation and monitoring of the results of the implementation of peat ecosystem conservation and restoration efforts is necessary. Monitoring and evaluation will identify gaps and opportunities for improvement and refinement of fire mitigation strategies. The sustainability of peat ecosystem conservation and restoration efforts requires strong policy support. The government needs to encourage policies that support the sustainable management of peat ecosystems, including incentives for parties involved in conservation efforts, strict supervision of destructive activities, and strict law enforcement against arsonists.

3.3 Collaboration between stakeholders

The role of the government is crucial in formulating policies and implementing forest fire disaster mitigation programmes that focus on peat ecosystems. The government can create regulations governing peatland management, involve various related institutions, and provide a budget to support peat ecosystem conservation and restoration efforts. Collaboration with local communities is a key element in conserving and managing peat ecosystems. Local communities have valuable traditional knowledge of peat ecosystems and can act as natural watchdogs and partners in vegetation restoration, fire monitoring, and the prevention of illegal burning. Through participatory approaches, local communities can be involved in decision-making regarding peatland management. By involving them in the planning and implementation process, there will be a shared understanding and greater responsibility for the sustainability of the peat ecosystem.

Company involvement is also important in implementing sustainable land management practices. Companies are significant land users and can contribute to the restoration and maintenance of peat ecosystems through responsible practices such as minimizing new land clearing, restoring land, and reducing greenhouse gas emissions. The importance of collaboration between the government, local communities, and companies in supporting peat ecosystem conservation and restoration efforts Through dialogue and strong partnerships, there can be a clear division of roles, an exchange of knowledge and technology, and strict monitoring of activities that have the potential to damage peat ecosystems. In addition, coordination between stakeholders is also needed to overcome conflicts of interest that may arise in peatland management. With open dialogue and joint solutions, an agreement can be reached that benefits all parties and maintains the sustainability of the peat ecosystem.

The involvement of research institutions and academics can also strengthen collaboration between stakeholders. These institutions can provide a deeper understanding of peat ecosystems, provide data and information needed for decision-making, and support the development of research and innovation in peat ecosystem management. Transparency and accountability in stakeholder collaboration are essential. Disclosure of information on

peatland management activities, commitment to sustainable practices, and structured reporting will increase trust and strengthen cooperation between stakeholders.

Formal dialogue forums and coordination mechanisms between stakeholders are needed. This can take the form of coordination meetings, working groups, or specialized institutions that aim to facilitate collaboration, share information, and monitor progress in implementing peat ecosystem conservation and restoration efforts. Collaboration between stakeholders in peat ecosystem implementation requires long-term and sustainable commitment. Continuous cooperation, periodic evaluation, and strategy adjustment are necessary to achieve the common goal of maintaining the sustainability of peat ecosystems.

3.4 Challenges and opportunities in peat ecosystem implementation

The challenge of climate change is one of the obstacles to maintaining the sustainability of peat ecosystems in Riau. Changing rainfall patterns, increasing temperatures, and fluctuating water levels can disrupt sensitive peat conditions. Faced with these challenges, effective adaptation strategies are needed to maintain the moisture and sustainability of peat ecosystems. Socio-economic challenges also have a significant impact on the implementation of peat ecosystem mitigation. Population growth, urbanization, and land conversion increase the pressure on peatlands. The need for agriculture, plantations, and infrastructure can threaten the sustainability of the ecosystem. Mitigation efforts must address these challenges through sustainable and community-based approaches. Land conversion is a serious challenge to maintaining the sustainability of peat ecosystems. Conversion of peatland to agriculture or plantations increases the risk of fire and damages the hydrological function of peat. Sustainable land management and control of land conversion are key to maintaining the sustainability of peat ecosystems.

Despite these challenges, there are opportunities for technology development and innovation that can strengthen forest fire mitigation in peat ecosystems. The use of remote monitoring systems and satellite technology can help detect fires early and speed up emergency response. In addition, the use of innovative fire control methods, such as drip torches or water-carrying helicopters, can increase the effectiveness of fire suppression. Another opportunity is the development of restoration and rehabilitation programmes for degraded peat ecosystems. By involving local communities and stakeholders, peat vegetation restoration and hydrological reconstruction efforts can strengthen ecosystem resilience to fire and climate change. A community-based approach is an important opportunity for implementing peat ecosystem mitigation. By involving local communities as partners in ecosystem management and maintenance, long-term sustainability can be achieved. Strengthening community capacity for understanding and active participation will help overcome socio-economic challenges that affect mitigation implementation.

Another opportunity is collaboration between institutions and stakeholders to support the implementation of peat ecosystem mitigation. Synergies between the government, communities, companies, and non-governmental organizations can create a common strength in overcoming challenges and taking advantage of opportunities. The development of education and public awareness programmes on the importance of peat ecosystems is also an opportunity that needs to be exploited. By increasing understanding of the benefits of peat ecosystems and their contribution to forest fire mitigation, communities will play a more active role in their conservation and sustainable management.

Utilization of available funds and resources is an opportunity that can strengthen mitigation implementation. Through proper allocation of funds and efficient utilization of resources, mitigation programmes can be implemented effectively and sustainably. The last opportunity is international support and regional cooperation in the implementation of peat ecosystem mitigation. Cooperation with other countries that have similar peat ecosystems

can provide learning and knowledge exchange, as well as financial and technical support that can strengthen mitigation efforts.

4 Conclusion

Based on this discussion, the implementation of peat ecosystems in mitigating forest and land fires in Riau has several challenges that need to be overcome. Climate change, socio-economic challenges, land conversion, and other inhibiting factors are factors that affect the success of the mitigation program. However, in facing these challenges, there are opportunities that can be utilized, such as technology development, collaboration between stakeholders, and peat ecosystem restoration programs. The importance of conservation and restoration of peat ecosystems as an important step in strengthening ecosystem resilience is an important point in the implementation of mitigation. Restoration of peat vegetation, construction of irrigation canals, and integrated fire management are relevant strategies for maintaining moisture and reducing fire risk in peat areas. In addition, collaboration between stakeholders, including the government, local communities, and companies, is key to implementing sustainable land management practices.

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